AL-CR-1991-0008

AD-A245 198

FORCE STRUCTURE VALUATION MODEL

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January 1992

Final Contractor Report for Period January 1987 – December 1991

Approved for public release; distribution is unlimited.

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235-5000

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
January 1992

3. REPORT TYPE AND DATES COVERED
Final – January 1987 – December 1991

4. TITLE AND SUBTITLE
FORCE STRUCTURE VALUATION MODEL

5. FUNDING NUMBERS
C – F33615-87-C-0006
PE – 62205F
PR – 7719
TA – 20
WU – 22

6. AUTHOR(S)
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Advanced Technology, Incorporated
12001 Sunrise Valley Drive
Reston, VA 22091

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)
Armstrong Laboratory
Human Resources Directorate
Manpower and Personnel Research Division
Brooks Air Force Base, TX 78235-5000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
AL-CR-1991-0008

11. SUPPLEMENTARY NOTES
Armstrong Laboratory Technical Monitor: Larry T. Looper, (512) 536-3648

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
This report documents research to develop a methodology to determine the value of Air Force experience and training in Air Force occupations. Based on human resource accounting and human capital theory, two alternative models were developed. The first approach focused on estimating the value of military occupations based on the market value of similar civilian occupations. The second focused on estimating the value of military occupations based on productive capability—the amount and quality of work performed. Both models were then used to estimate the impact of retention changes on the force structure of a selected Air Force specialty (328x0—Avionic Communications Specialist). Suggestions for future research and how to use the two models for force structure decisions are offered.

14. SUBJECT TERMS
Force structure model
Human captail
Human resources accounting
Productive value

15. NUMBER OF PAGES
38

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500
Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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TABLE OF CONTENTS

LIST OF FIGURES

PREFACE

The research documented in this technical paper was accomplished as part of Project 7719, Force Acquisition and Distributions Systems and Task 771920, Manpower and Personnel Models. The specific work unit, 77192021, is titled Technology to Assess the Value of Air Force Experience (PRDA 2). This work is a logical extension of several years of previous research to capture the economic and policy factors important to enlisted and officer accession and retention behavior. The ultimate goal is a methodology usable by Air Staff to support force structure decisions (e.g., pay, selective reenlistment bonuses, retirement policies, etc) and to make the best use of limited fiscal resources to build a qualified mission-capable force.

FORCE STRUCTURE VALUE MODEL

SUMMARY

This technical paper documents research completed to develop a methodology to estimate the value of experience and training in Air Force occupations. The focus of the research was on the valuation of force structures composed of differing levels of skilled personnel. A model was developed based on the work of Dr. Eric Flamholtz at UCLA in human resource accounting which expresses value as a series of current and expected future values. This project analyzed two alternate ways to measure the value of a force structure. The first model used a market value approach based on direct comparison of wages in similar civilian occupations. Age earning functions were equated to military members at a specific year of service. Summing over all years of service an entire force structure was valued. The second approach focused on productive capability. A functional relationship was estimated between experience and the amount of work performed (supervisory and technical) productive value in an occupation. Aggregating across individuals in an occupation, the entire productive value of a particular force structure was estimated. The impact of changes in force parameters such as retention were then estimated to determine the differing value of a more senior versus a less senior force for both approaches. Suggestions are offered on how to use such models in force structure decisions and on future research directions.

INTRODUCTION

This paper presents a methodological approach to human resource valuation by integrating human resource accounting and human capital models with military resource management to assess the relative value of alternative occupational force structures. An occupational force structure is defined as the number of military members by year of service (YOS) within a particular Air Force specialty (AFS). Alternative force structures are developed by modifying the retention rates of individual YOS groups, then aging the force over time utilizing these modified rates. This approach provides two different force structures, each with the same number of members but with varying amounts of experience as illustrated in Figure 1. In comparing the two force structures, force structure 1 can be characterized by lower retention and lower aggregate experience level than force structure 2. This approach also allows the following kinds of questions to be addressed: Does force structure 1 have lower productive potential than force structure 2? If so, how much more?

In a free market, the value of "goods and services" (or output) is regulated by supply and demand forces in the economic system. Attributing value (price) to output is possible for many commodities, since value is determined in part by what consumers are willing to pay. Attributing value to an individual Air Force member's output of services, however, has historically been an elusive problem since the Air Force does not operate in a free market. This has left the Air Force vulnerable to arbitrary resource reductions as it has been unable to quantify the value derived from human resources. Being able to quantify the value of these resources would provide Air Force managers with the capability to:

1. Determine the impact of policies that alter a given force structure's distribution of personnel by year of service,

2. Provide a defense against arbitrary reductions in force structure grade, skill level, or experience, and

3. Aid in placing a "price tag" on retention initiatives required to modify existing force structures.

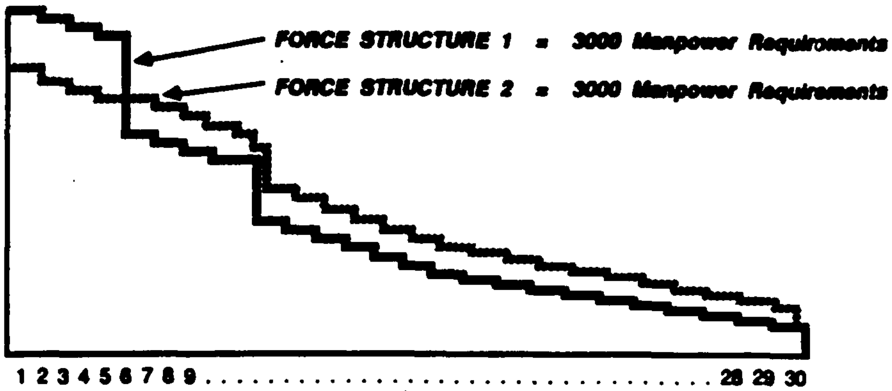


Figure 1. Alternative Force Structures

Addressing these concerns in the context of Figure 1 requires the development of unique value measures since the Air Force's public sector "economy" is obviously different from the private sector economy. In the private sector individuals are valued according to market forces. This process allows members with a given level of experience to leave and enter different organizations with compensation commensurate with their skills and experience. In the military, however a "closed market" exists and new, inexperienced individuals can enter the service only at an initial entry point. There is actually a limited accession of experienced personnel from outside the military service. Prior service enlistments have averaged just under *four percent* of total enlistment and accounted for from nine percent to less than one percent of total enlisted Air Force accessions during the last ten years (Quarterly Enlisted Retention Report, 1988). To meet future manpower requirements the Air Force must retain a percentage of its new personnel. While a private sector organization has the potential to increase the experience mix by adding experienced members, the military, after each YOS group enters active duty, depends primarily on retention patterns over time to dictate the experience content of its future force structure. For example, the only source of F-15 avionics specialists with six years of experience is former or currently active personnel with this level of experience.

Thus, the Air Force has a unique problem when attempting to place a value on occupational force structures. Because of the "closed market" environment, the Air Force must grow its own experience and define the value of that experience in useful terms. In the following sections this paper will develop methods to enable the Air Force to determine the relative value of existing and proposed force structures. Section II presents the human capital underpinnings of this research. Section III discusses current value estimation techniques with Sections IV and V introducing the applications of these techniques to the problem domain. Section VI briefly summarizes the effort and presents the next steps to be taken.

A HUMAN CAPITAL APPROACH

Contemporary human capital theorists have conceptualized that a member's value to an organization must be determined not only from the value of present services but also by the value of services a member will potentially contribute in the future (Flamholtz, 1986). The concept of a member's future service having economic value today is the foundation of contemporary human capital thought. Conceptualizing the value of experience in this way requires the determination, in

economic terms, of the worth of a member's work to the Air Force. It also requires determining the expected value of a member's services in the future, given the condition that he/she is presently in a given YOS group. By definition then, an individual member's value of Air Force experience (V_i) at any point in his/her career, is the member's current value (CV_i) to the Air Force plus the member's conditional expected future value ($CEFV_i$) to the Air Force given that he/she is currently a member of the ith YOS group. Expressed notationally:

$$V_i = CV_i + CEFV_i \tag{1}$$

Theoretically, CV_i may be expressed in present year terms of competitive market cost or a relative measure of a cohort's productive capability. $CEFV_i$ can be expressed as a series of CV_i's adjusted for retention and the time value of money. Determining the current value of a military member's contribution to the Air Force appears straightforward; but, in fact is quite difficult.

Conditional Expected Future Value

The conditional expected future value of an Air Force member's experience is the expected future value to be derived from a member's services given that he/she has arrived at a given YOS. Each YOS can be conceptualized as a node in a transition network (Clarke & Disney, 1985) as depicted in Figure 2's simple five year example.

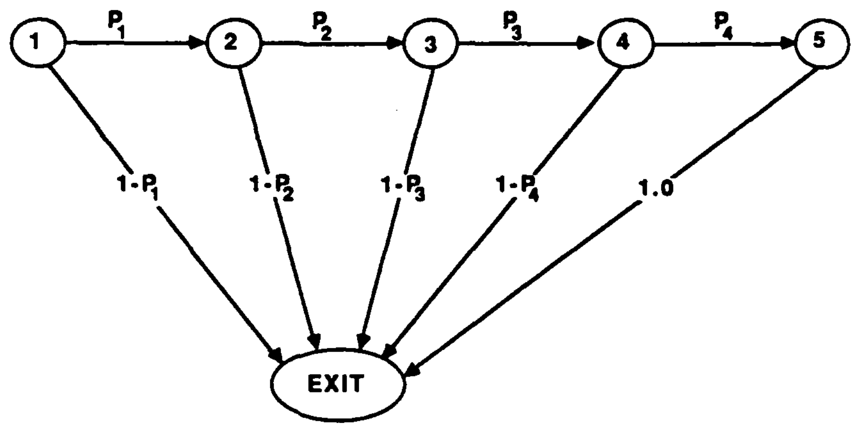


Figure 2. Transition Network

Associated with each node is a transition probability of passing from that node to the next. P_1, in Figure 3, is the transition probability associated with completing the first YOS and entering the second YOS. The Markovian states associated with the network are defined as the completion of a given number of years of service during an average career. Here State 1 is defined as completing the first year only. State 2 is defined as completing two years of service. In this transition network State 5 is the successful completion of an entire career.

In Figure 2 the term $1 - P_1$ is the loss rate of the first year group and is the percentage of members never achieving state 2. Historically, it is possible to obtain the transition probabilities (retention rates) between nodes. With the values of P_1 through P_5, in Figure 3, the mutually exclusive probabilities of completing and exiting each state can be computed. Note that the probabilities in Figure 3 are contrived for illustration purposes. In a practical application the probabilities for each YOS state would be different.

YOS State	Pn	1 - Pn	Probability	
1	.80	.20	.20	= .20
2	.75	.25	.80(.25)	= .20
3	.67	.33	.80(.75)(.33)	= .20
4	.50	.50	.80(.75)(.67)(.50)	= .20
5	1.00	.00	.80(.75)(.67)(.50)(1.00)	= .20
				1.00

Figure 3. Years of Service and Expected Loss Rates

If a value is assigned to the services provided in each year (CV_1 through CV_n) then the value associated with completing each state along with the probability of completing each state can be used to determine the expected value to be derived from each state. If a member completes only the first state the value to be received is only CV_1. If the member completes all five states, the value to be derived is $CV_1 + CV_2 + CV_3 + CV_4 + CV_5$ as depicted in Figure 4.

YOS State	Probability	Value of Completion
1	.20	CV_1
2	.20	$CV_1 + CV_2$
3	.20	$CV_1 + CV_2 + CV_3$
4	.20	$CV_1 + CV_2 + CV_3 + CV_4$
5	.20	$CV_1 + CV_2 + CV_3 + CV_4 + CV_5$
	1.00	

Figure 4. Value of Services Across Years

The value of Air Force experience (V_i) expected to be received from an individual in the first YOS is:

$$V_1 = CV_1 + CEFV_1. \tag{2}$$

Expanding $CEFV_1$ as a series of current values leads to:

$$\begin{aligned} V_1 = CV_1 & \\ &+ [O \times (1 - P_1)] \\ &+ [CV_2 \times P_1 \times (1 - P_2)] \\ &+ [(CV_2 + CV_3) \times P_1 \times P_2 \times (1 - P_3)] \\ &+ [(CV_2 + CV_3 + CV_4) \times P_1 \times P_2 \times P_3 \times (1 - P_4)] \\ &+ [(CV_2 + CV_3 + CV_4 + CV_5) \times P_1 \times P_2 \times P_3 \times P_4 \times (1-P_5)] \end{aligned} \tag{3}$$

Note that the future value of not transitioning from year one to year two is zero. This means the Air Force receives no future value from a member who fails to continue beyond his first year of service. After expanding all terms, the above expression for V_1 reduces algebraically to:

$$
\begin{aligned}
V_1 = CV_1 & \\
& + [CV_2 \times (P_1)] \\
& + [CV_3 \times (P_1 \times P_2)] \\
& + [CV_4 \times (P_1 \times P_2 \times P_3)] \\
& + [CV_5 \times (P_1 \times P_2 \times P_3 \times P_4)].
\end{aligned} \tag{4}
$$

The simplified expression for V_1, contained in equation (4), is used throughout this research in lieu of the more complex equation (3). Equation (4) illustrates that the value of a member's experience is equivalent to the current value of the services (CV_1) plus the conditional expected future value of all services in the future. The conditional expected future value is the expected value to be derived from all future years. The future value to be derived from year two, given a member is in year one, is the value of services in year two (CV_2) times the probability of transition from year one to year two. The future value to be derived from year three, given a member is in year one, is CV_3 times the probability of transitioning from year one to year three (P_1 x P_2). A parallel discussion holds for years four and five.

Present Value Discounting

Conditional expected future value determines how much value an individual member's service can be expected to provide in the future, given the member has arrived at a certain point in his/her career. The conditional expected future value, however, is an estimate of services to be provided in the future. The value of these future services cannot be directly compared to the value of present services since it is estimated for different time periods. To correct this problem present value discounting is used to adjust the value of services provided in the future to present value terms.

To convert future value to present value the following relationship is utilized:

$$\text{Present Value} = \text{Future Value}/(1 + d)^i \tag{5}$$

where i = any year in the range [1,30]
d = the discount rate.

This discounting assures that all conditional expected future values are converted to present value equivalents. When this adjustment is applied to equation (4) the following expression for V_1 is obtained:

$$
\begin{aligned}
V_1 = [CV_1 / (1 + d)^1] & \\
& + [(CV_2 \times P_1) / (1 + d)^2] \\
& + [(CV_3 \times P_1 \times P_2) / (1 + d)^3] \\
& + [(CV_4 \times P_1 \times P_2 \times P_3) / (1 + d)^4] \\
& + [(CV_5 \times P_1 \times P_2 \times P_3 \times P_4) / (1 + d)^5].
\end{aligned} \tag{6}
$$

Note that the current value for the first year (C_1) receives a one year present value adjustment. This arises because of the assumption that the value from a member's services is obtained at the end of the year. Value received at the end of the first year must be adjusted to the beginning of the first year to determine the present value of CV_1.

Force Structure Mechanics

The expanded definition of V_i provides the functional relationship for determining force structure value. With a definition for V_i the value of a YOS group can be defined as the product of the number of members in a YOS group times its value.

$$\text{YOS Group Value}_i = m_i \times V_i \tag{7}$$

where m_i = Number of members in YOS_i,
V_i = value of experience of a member in YOS_i, and
i = the year of service.

The value of experience for a force structure is then defined as the sum of the value for all YOS groups in that speciality:

$$ForceStructureValue = \sum_{i=1}^{30} (m_i x V_i) \tag{8}$$

With the above definition, a value for a given force structure can be calculated. Likewise, alternative force structures can be assigned a value which can be compared against the original force structure value. This provides a method for defining the value of experience for force structure alternatives in a military context.

The development of an expression for force structure value produces a function dependent on the number of members in various year groups and the value of experience of those year groups. The value of experience in turn is dependent on the current value of the year groups and their conditional expected future values. With given discount and retention rates, the conditional expected future value can be expressed in current value terms. This model requires the development of a useful current value estimate.

CURRENT VALUE

Section II presented a method for assessing the value of alternative military force structures. The method requires a determination of a military member's current value to the service as defined in Equation (1). However, the nature of the military's public sector "economy" does not allow a straightforward valuation of output as in the private sector. The task, therefore, is to find a method, a set of metrics, or surrogate measures for current value. The complexity of defining current value and the relationship between force output and value of output is illustrated in Figure 5.

In the private sector the value of output could be obtained from the marketplace's pricing mechanism. Cost of the output would also be known through traditional cost accounting methodologies. Military output also possesses value, but unfortunately, a direct way to measure the value of the output is unavailable. Ways of obtaining the price of substitute resources or of determining the demand for the product are needed. This indirect approach is also beset with problems, since knowing how much output is enough, what is the demand, and the cost to buy the output product are difficult to determine.

In addressing the value of alternative force structures, it is necessary to establish a cause and effect connection between experience expressed in years of service and the value associated with that service. Figure 5 points out that more than an experienced force structure is required to provide force output. However, measuring all of these inputs such as the influence of the management environment and the impact of material resources, is as elusive as value itself. Therefore, it is necessary to express value as a function of the amount of experience while controlling for the effects

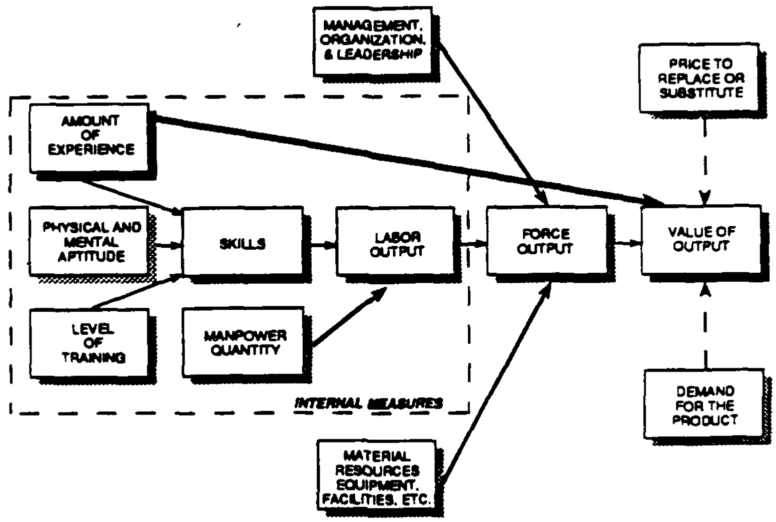


Figure 5. Current Value Concept

of physical and mental aptitude, training, management, and other resources.

Two surrogates for the current value of military members were examined. The first metric, market value, seeks to place a market-oriented price on replacement or substitute resources which could be used to obtain military output. The second metric relates internal Air Force measures as depicted in Figure 5 to force output and is referred to as productive value. Before discussing either one of these concepts, it is important to lay down a set of criteria that both metrics must satisfy to be useful to the Air Force.

Selection Considerations

The need for metric selection considerations arose while developing a measure of current value between occupational YOS groups. This proved to be a difficult task because Air Force occupations are complex. Military members do not learn a task or a group of tasks and then repeat only those tasks throughout a career. Individual members learn tasks; and as they mature, they add additional technical tasks to their inventories or they drop previously learned technical tasks from their inventories as they gain additional supervisory responsibilities.

Since Air Force members work and progress in their careers in specified occupational structures, the measure of current value must also be occupational, that is, it must consider the following:

1. Changing task inventory - the shift over a career of percent time spent (PTS) on technical versus supervisory duties,

2. Changing task difficulty - the shift over a career of average task difficulty, and

3. Differing duty weights - the observation that technical and supervisory duties have different value and must be weighted (W_t & W_s) differently.

Besides the occupational considerations, a useful current value metric should satisfy several other important considerations. It should be derived from data that are easy to obtain or already exist within the Air Force data system environment. The metric should be intuitively appealing and provide broad coverage applicable to all Air Force specialties. Finally, it must relate to output defined in such terms as readiness, or capability of an entire force structure. In summary, five criteria exist which any useful estimate of current value should satisfy. A current value metric should be:

1. Occupational - addresses the phenomena of changing task inventory and difficulty over a career,

2. Obtainable - based on data that are easy to obtain or already exist,

3. Defensible - provides both intuitively appealing and non-mysterious results with face validity,

4. Applicable - can be broadly applied to all AFSs, and

5. Relatable - to force output, readiness, or capability.

Any current value approach should be scrutinized using these criteria. Only through satisfying these criteria can a current value metric be considered useful to the Air Force. Therefore, when examining surrogates for current value such as market and productive value, it is important to determine whether they satisfy the unique occupational aspects of military work. The following sections present two approaches to developing current value surrogates. The market value approach utilizes compensation analysis. The productive value approach utilizes insight from occupational and job performance measurement program data.

Market Value

The first approach to developing current value estimates makes use of results from the Fifth Quadrennial Review of Military Compensation (QRMC) performed for the Office of the Secretary of Defense (Department of Defense - Office of the Secretary of Defense, 1984). This study looked at the issue of military compensation and its relation to retirement benefits. One result of the QRMC study was a comparison of compensation levels from civilian occupations to similar enlisted and officer military occupational groupings. The market value model employed was:

$$\text{Market Value} = b_o + (b_1 Y + b_2 Y^2) \tag{9}$$

where: Y = Year of service (YOS)
b_o, b_1, b_2 = regression coefficients that apply to particular occupational groupings.

Equation (9) provides a current value dollar model and an estimate of the values that the labor market places on Air Force skills by varying levels of experience (YOS). QRMC data showed that civilian market value increases as experience increases over the employment years associated with military service. An increase in experience in traditional civilian occupations is associated with increased variety and difficulty of tasks performed. Thus, value can be conceptualized as a function of experience which in turn is related to the ability of individuals to perform a greater number of more difficult tasks. In this market value approach, it is assumed that a parallel phenomena takes place in military occupations with a similar job description.

Productive Value

The productive value approach seeks to develop a current value metric which is an internal measure of force output. To develop this internal measure some knowledge of military work is necessary. Military work can be described with two dimensions. First, there is the quantitative dimension of work that provides a measure of how much work is being accomplished. An increased capacity to perform technical work is intuitively related to experience. The second dimension of military work relates to the learning difficulty of jobs/tasks and provides a measure of the relative time to gain proficiency in a job/task. Thus, the relative contribution of individual specialists to their occupation's force output is related to the amount of work produced and the difficulty of that work.

The productive value of a member's output should be measured as a function of the member's productive capacity considering the task inventory being performed. This research pursued several approaches to obtaining productive value measures which were all developed in the context of available Air Force data systems. The most promising of these was a two-stage approach that initially developed a measure of productive value based on a selected subset of technical duties with the second stage extending the measure to all tasks in an occupation's inventory.

Stage One

The Air Force's Time to Proficiency (TTP) research effort (Carpenter, Monaco, O'Mara & Teachout, 1989) was the first step to obtain productive value measures. The TTP measurement effort was initiated to obtain accurate measures of job performance by different specialists using economic survey instruments. The TTP effort was conducted during the Air Force's Walk-Through Performance Testing (WTPT) effort which utilized "hands-on" measurement of specialist job performance (Hedge, 1984). One of the major objectives of the TTP effort was to determine the feasibility and validity of using supervisor estimates as measures of performance. In order to achieve this objective, the avionic communications specialty (328XO) was selected and data collected from supervisors concerning the relative proficiency of their subordinates. The TTP research effort showed that for first-term airmen, technical proficiency is indeed a function of experience (Carpenter et al, 1989).

The TTP questionnaire considered a member's task inventory, the relative rate at which tasks were performed within the inventory, and the supervision required for a member to perform ten groups of tasks. Information was provided by a sample of supervisors of first-term airmen in the AFS. Each supervisor indicated the relative frequency with which each subordinate performed tasks in each task group. These task groups were constructed so that each was homogeneous with respect to difficulty and had a high degree of co-performance among tasks in the group. Co-performance refers to a given task in a task group that is not performed unless other tasks in the group are also performed by the same individual.

The groups were also formed to span the range of difficulty experienced by first-term members of the AFS. Each supervisor selected a "bench mark" individual for each task within each task group. The supervisor then estimated how long it would take each of his subordinates to perform the equivalent amount of work within each task group that the "bench mark" worker would complete in one hour. Each supervisor also estimated the amount of supervision time that each of his subordinates would require to complete the specified amount of work in each task group. Based on the data from the TTP study, this current effort developed a productive value measurement for technical jobs/tasks. Combining TTP data with job difficulty measures from AFHRL's Occupational Research Data Bank (ORDB) four components were identified:

1. Difficulty - The average learning difficulty of tasks in a task group.

2. Frequency of Performance - The supervisor's assessment of the relative frequency (never, occasionally, regularly) with which each airman performed tasks in a task group.

3. Performance Time - The supervisor's estimate of the time an airman would take to complete a "bench mark" unit of work in a task group.

4. Supervisory Time - The supervisor's estimate of the time required to supervise an airman while performing a "bench mark" unit of work in a task group.

The relative productive value for technical jobs/tasks was then computed as a weighted sum of output/input ratios across all task groups. Output for each task group was measured in "bench mark units" (BMU). Each unit of output was valued at the level of learning difficulty associated with the corresponding task group. Input for each task group was measured in units of performance and supervision time. For each task group, output was divided by input to derive the difficulty per unit of labor as represented in Equation (10).

$$PV_t=\sum_{j=1}^{10}\frac{(D_j x F_j)}{(P_j+S_j)} \tag{10}$$

where: j = task number in the range [1,10]
D_j = difficulty of task j
F_j = relative frequency of performance of task j
P_j = performance time of task j
S_j = supervisory time of task j.

To compute the relative frequencies of performance, the numbers 0, 1, and 2 were respectively assigned to the TTP responses "never", "occasionally", and "regularly". For each task group, the corresponding response number was divided by the response numbers summed across all task groups. These ratios indicated the relative proportion of an airman's time spent in each task group. PV_t was computed as the products of output/input and frequency ratios summed across all task groups. PV_t measured the value, in terms of task difficulty, of the work produced during the average hour of labor. PV_t was expressed as occupational difficulty times bench mark units per labor hour.

PV_t was computed for a sample of first-term members of AFS 328X0. A log-linear model was estimated to relate PV_t to experience as shown in Equation (11).

$$PV_t=axY^b \tag{11}$$

where Y = experience expressed in YOS
a,b = estimated parameters.

Figure 6 graphs the estimated relationship for AFS 328X0 over 30 years with a = 2.3827 and b = 3754. Only the first four years of service were measured in the WTPT and TTP efforts. The remaining values were extrapolated. Obviously additional observations between the 4th and 30th YOS would

be essential to enhance the utility of the PV_t expression. Additionally, the TTP approach only addressed the technical (direct) work performed by a specialist and did not account for changes in task inventory shifts from technical to supervisory over a career. These considerations were addressed in stage two of the approach.

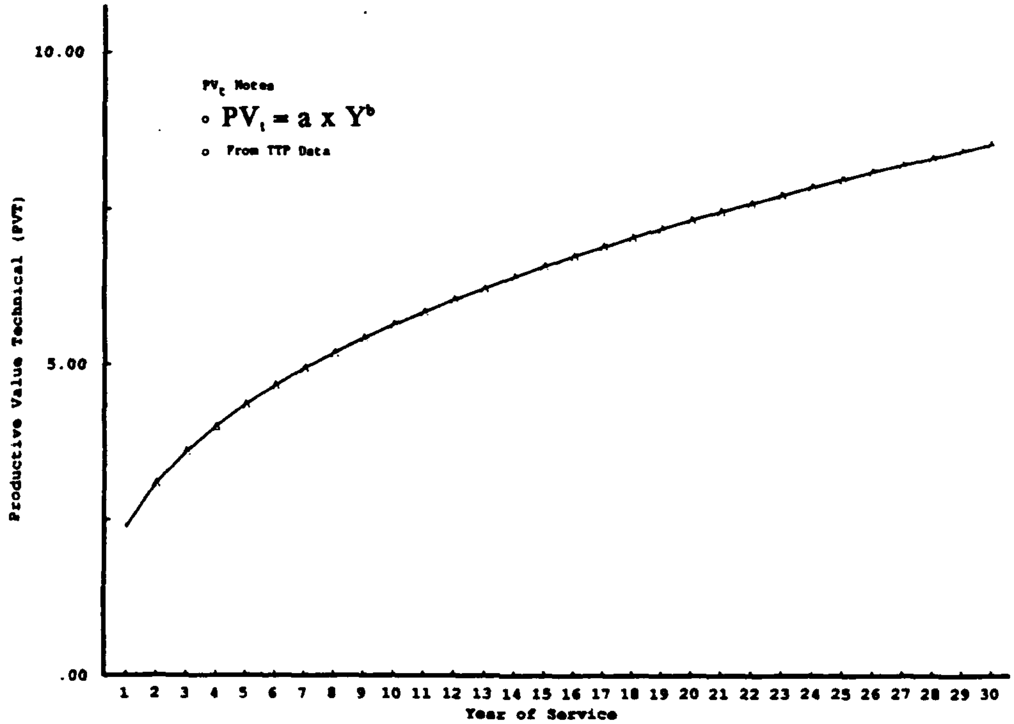


Figure 6. Productive Value - Technical (PV_t)

Stage Two

The next stage in the development of a productive value measure relied on data from AFHRL's Occupational Research Data Bank (ORDB). This data base provided an avenue to assess changes in technical versus supervisory duties during the course of an Air Force career. ORDB inquiries were constructed to capture changes or shifts in occupational duties. The ORDB places tasks into duty categories. See Appendix A for AFS 328X0 categories. In this two-stage approach ORDB duty categories were assigned to one of two occupational activities:

Supervisory Activity - Duty category A through D
Technical Activity - Duty category E through Z

The ORDB was also used to obtain Average Task Difficulty Per Unit Time Spent (ATDPUTS) by YOS for these activities in addition to the percent time spent (PTS) by YOS on each activity. ATDPUTS is an accepted measure of occupational learning difficulty (Burtch, et al., 1982). It provides a useful way to estimate the relative change of difficulty of an individual's task inventory over a career. A detailed description of how ATDPUTS data are used in this calculation is contained in Appendix B.

The relative time spent among supervisory and technical activities was assumed to be the same for individual occupations; that is, the relative increase in the value of occupational duties was a result of increases in both technical proficiency and supervisory duties. Using this assumption a weight or difference in value between technical (W_t) and supervisory (W_s) activity was developed. A linear combination of the productive values associated with technical and supervisory activity was examined.

This linear combination follows the general form:

$$PV_i = (W_t \times PV_{ti}) + (W_s \times PV_{si})$$

since $W_t + W_s = 1$, then

$$PV_i = W_t \times PV_{ti} + (1 - W_t) \times PV_{si}, \quad O = W_t = 1 \tag{12}$$

The QRMC and the ORDB were used to estimate the relative value of technical and supervisory work as measured by those systems. The QRMC provided market value (MV) by YOS, while the ORDB provided percent time spent in supervisory tasks (PTS_s) by YOS. Matching by YOS, ordered pairs of MV and PTS_s were obtained. The following linear function was used to model these ordered pairs:

$$MV_i = c + (b \times PTS_{si}) \tag{13}$$

Using ordinary least squares regression analysis, estimates were obtained for the parameters c and b. Equation (13) was then rewritten as:

$$MV_i = c \times (1 - PTS_{si}) + (b + c) \times PTS_{si}. \tag{14}$$

since $PTS_{ti} + PTS_{si} = 1.0$;
therefore, PTS_{ti} can be substituted for $(1-PTS_{si})$ giving:

$$MV_i = c \times PTS_{ti} + (b + c) \times PTS_{si}. \tag{15}$$

Equation (15) shows that the market places a value on supervisory activity which is (b + c)/c times greater than technical activity. Using Equation (12), the relationship of the weights for supervisory and technical time is $\frac{1 - W_t}{W_t}$

Setting $\frac{b + c}{c} = \frac{1 - W_t}{W_t}$ and solving for "W_t" yields:

$$W_t = \frac{c}{b + 2c}. \tag{16}$$

The value of W_t was estimated as approximately 0.27 for AFS 328X0 which, when substituted into Equation (12), yielded:

$$PV = 0.27 \times PV_t + 0.73 \times PV_s. \tag{17}$$

With these weights, (W_s & W_t) an estimate of productive value for both technical and supervisory activity was computed. In summary, the expression for productive value (PV) was constructed by:

1. Obtaining an expression for productive value applicable to technical work (PV_t) by YOS,

2. Developing a corresponding expression for supervisory work (PV_s), which in this case was $ATDPUTS_{si}$, by YOS,

3. Collecting from the ORDB the percent time spent on technical and supervisory work (PTS_t & PTS_s) by YOS and from the QRMC, market value (MV) by YOS to determine the relative weights between technical and supervisory work (W_t & W_s).

This process yielded the following expression for the productive value of an occupation's output by YOS.

$$PV_i = (W_t \times PTS_{ti} \times PV_{ti}) + (W_s \times PTS_{si} \times ATDPUTS_{si}) \tag{18}$$

where: i = YOS
PTS_{ti} & PTS_{si} from ORDB
$ATDPUTS_i$ from ORDB
PV_{ti} from TTP data
W_t & W_s estimated from QRMC and ORDB data.

Equation (18) provides an expression that addresses the full complexity of occupational activity and task proficiency by YOS. It utilizes the QRMC approach to determine the relative value of supervisory and technical work which must be addressed in a current value metric. Equation (18) also addresses changes in percent time spent (PTS) and occupational difficulty (ATDPUTS) over a career. All of these elements are necessary to address the complex changes in activity that take place in the course of an airman's career.

Other Approaches

The productive value concept resulted from evaluating a variety of approaches. Initially this research assumed that data from the Air Force's Job Performance Measurement System (JPMS) would be an input to the computation of PV_t (Hedge & Teachout, 1986). Data using the Walk Through Performance Testing (WTPT) procedure within the JPMS for avionics communications specialist, air traffic control operator, and jet engine mechanic were candidates. However, the expected relationship between PV_t and experience could not be found. This was attributed to the fact that task data from the WTPT program were unclustered while the TTP task data were clustered. This difference prevented use of the WTPT data in the PV_t expression, Equation (10).

Another approach to developing a productive value metric utilized the global technical proficiency (GTP) rating contained in the JPMS data base. The GTP is a rating by self, peers, and supervisor on a five point interval. It was hypothesized that the GTP would be a reasonable surrogate for the production oriented PV_t measure. However, its utility as a measure was also not applicable to this research. Its value increased rapidly to near maximum performance early in an airman's career causing it to be an intuitively unappealing measure for purposes of this research as discussed in Appendix C.

APPLICATION OF MARKET VALUE

The numerous calculations associated with the value of Air Force experience were too burdensome to handle without computer support. Therefore, a software package to support this

research was constructed. Tabularized output was too detailed for most discussions so a graphical display of calculation results was used to aid the analysis. This application discussion will utilize the graphical output produced during this research. Figure 7 graphically portrays the market value of AFSC 328X0, Avionic Communications Specialist, over a 30 year career using the following equation:

$$\text{Market Value} = [15{,}000.00 + (1{,}150.00 \times Y) + (-15.00 \times Y^2)] \tag{19}$$

The parameters contained in Equation (19) were obtained by curve fitting QRMC data using Equation (9). The use of such data in the market value model shows that market value is monotonically increasing over the years a military member is eligible for service. The adjusted market value, bottom plot in Figure 7, reflects an adjustment to market value in YOS_1 when an individual is in formal training and considered to have zero value for a portion of YOS_1. Thus the adjustment recognizes that a percentage of the market value associated with that year group is valued at zero.

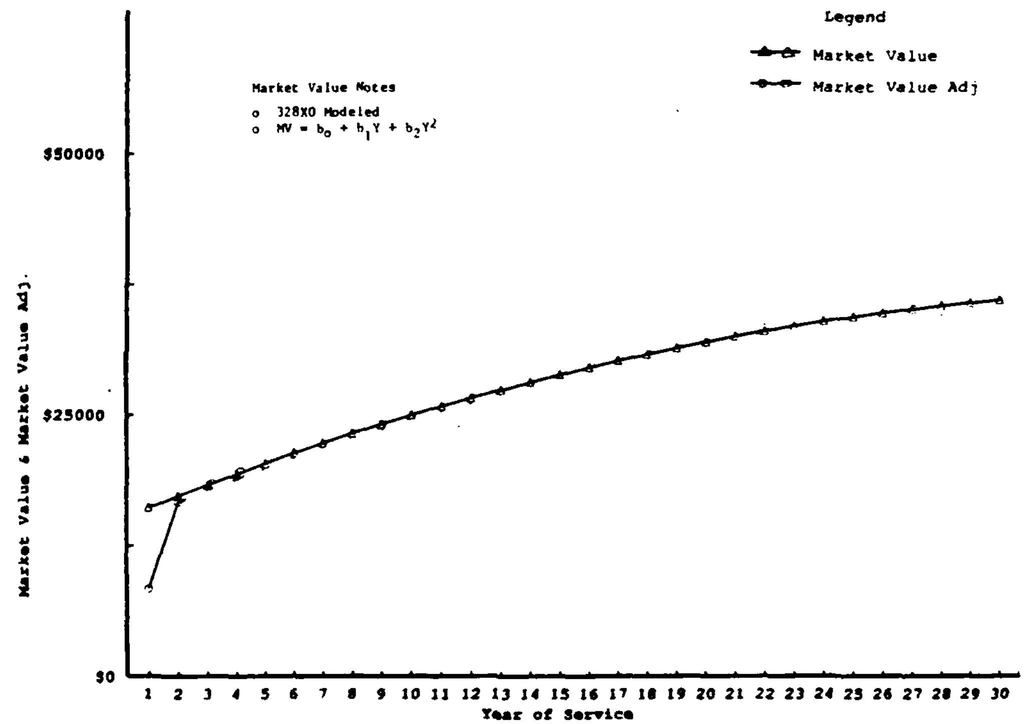


Figure 7. 328x0 Market Value

The second set of data needed to calculate the value of experience was the historical retention by YOS for the AFS under consideration. These rates, when used to age a given force under steady state assumptions, produce a force structure as illustrated in Figure 8. The force structure in Figure 8 depicts the distribution of airmen in YOS groups for a force of 3000. Changing a retention rate for any given YOS will change the shape of the force structure profile and the value of experience.

Utilizing the market value model in Figure 7 and the retention rates associated with Figure 8 the value of experience by YOS was calculated for the AFS. The value of experience is determined by current or market value plus the discounted sum of all the conditional expected future values

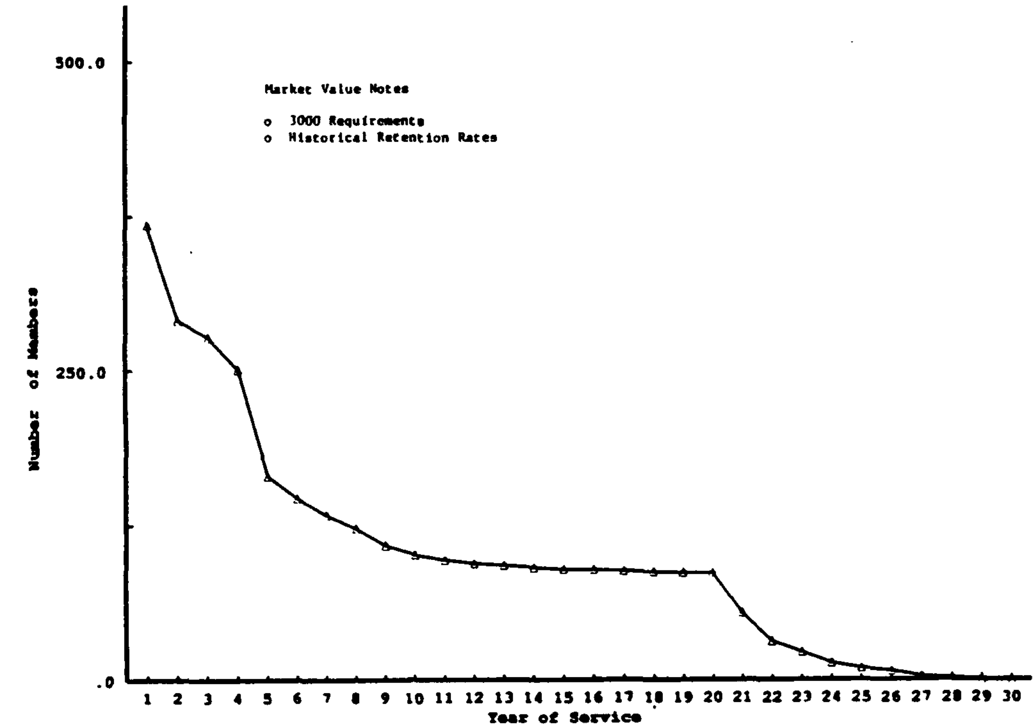


Figure 8. 328x0 Force Structure

(CEFV) based on retention rates. Appendix D shows the input of alternative discount rates on the value of experience. Based on the civilian non-farm employment cost index, a discount rate of 3.5% was used to discount the future value stream in this study (Monthly Labor Review, 1988).

In Figure 9, note the relatively low value of experience in the first through fourth YOS. The value of experience is directly related to retention rates. When retention is low, such as at the end of the fourth YOS, the value of experience of all previous year groups is depressed. This is because CEFV is a function of retention. The value of experience decreases toward the 20th YOS for the same reason. After the 20th YOS, the value of experience is low even though the current value is high. This is because there is a small probability that individual members will remain in service long enough to provide future value to the Air Force once they become retirement eligible and as high year of tenure rules begin to take effect.

Changes in retention will impact both the force structure and the value associated with individual cohorts. To illustrate this the retention rate in the AFS was reduced in its 12th YOS from .9838 to .6000. In the steady state, this induced a force structure profile change as depicted in Figure 10. Besides changes in the force structure, retention changes impact the value of experience for individual cohorts. These changes are reflected in Figure 11. The change of retention in the 12th YOS significantly impacted the value of the work performed for the Air Force by the 328x0 workforce during the first through twelfth years. This follows from the definition of V_i as a function of conditional expected future values which are determined in part by retention rates and current value.

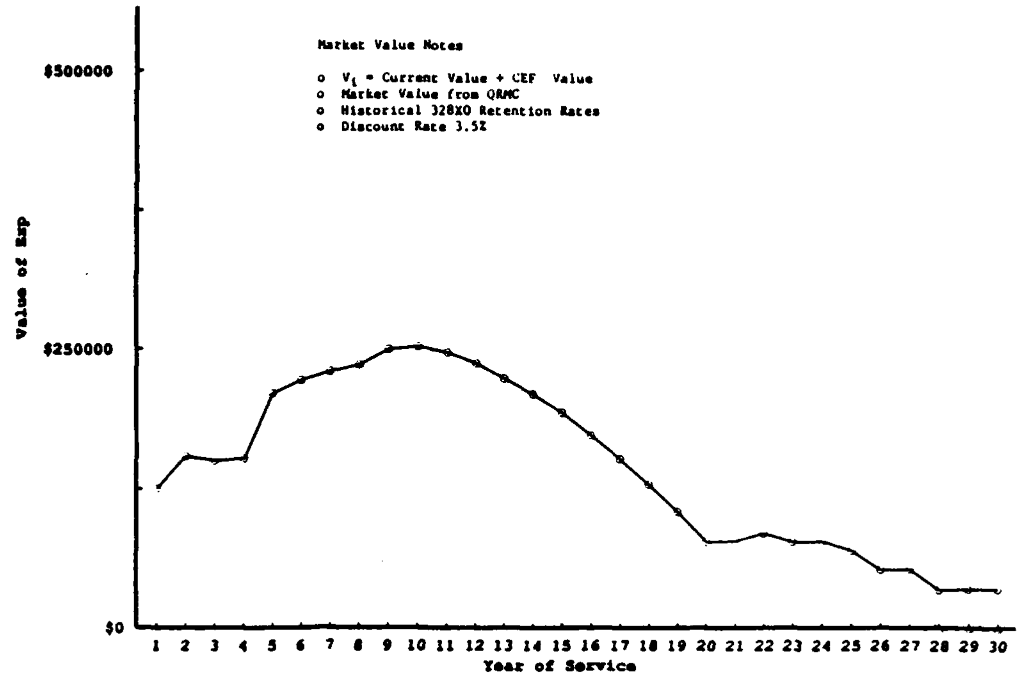


Figure 9. Value of Experience by YOS

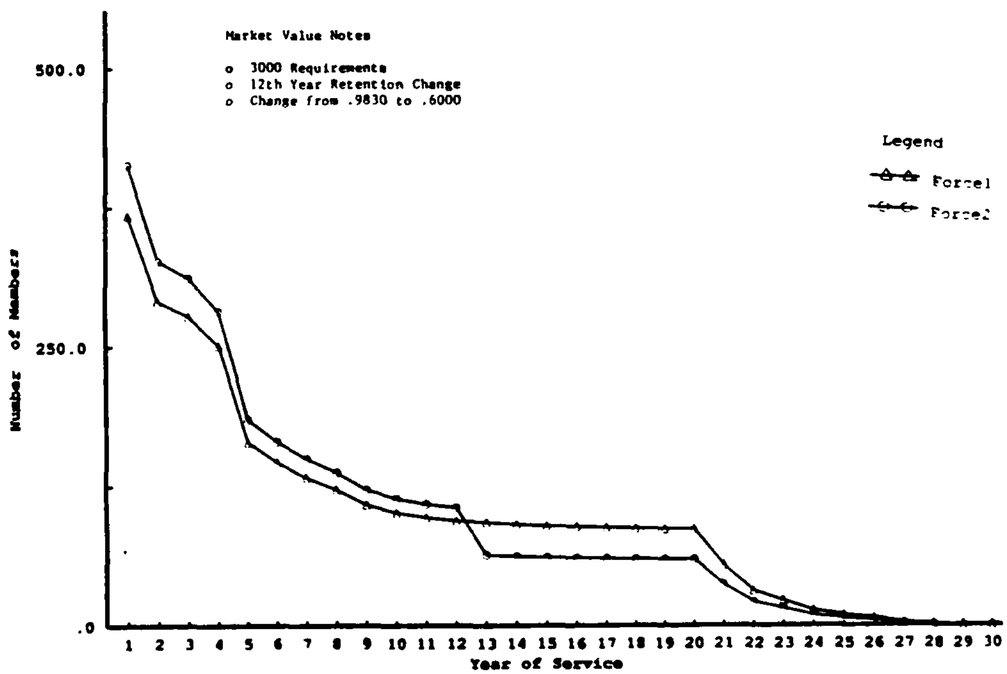


Figure 10. Force Structure Profile Change

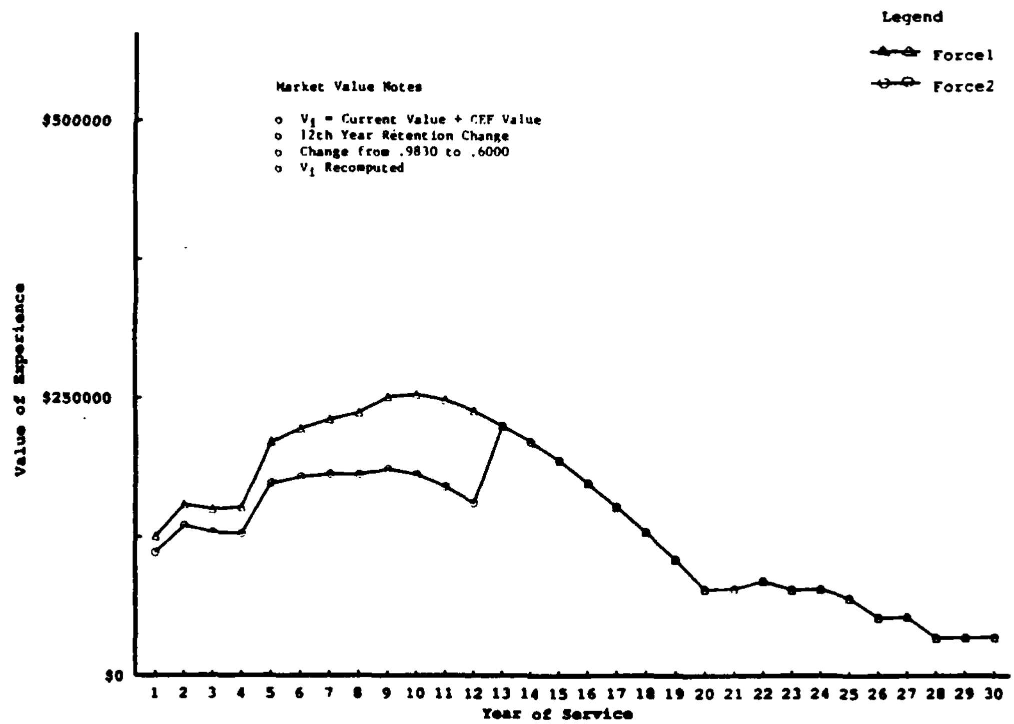


__Figure 11__. Value of Experience Changes

Force structure value was derived as a way to measure the relative value of two alternative force structures. In this application the alternatives are defined by differences in retention rates. Figure 12 provides a look at the cumulative value before and after retention changes. The cumulative value is obtained by summing the value (m_i x V_i) for each YOS group. The cumulative value (or force structure value) of work performed is $518M for the higher retention rate alternative. The force structure value for the lower retention alternative is $441M. Low retention decreases the overall value of experience of a force structure using the human capital definition of value.

Results observable from the application of a market value approach are that:

1. The 10th YOS is the most valuable group and should receive increased management attention (Figure 9),

2. Retention has a profound impact on the value of individual YOS groups (Figure 11),

3. Retention influences the value of YOS groups prior to the year retention changes are realized (Figure 11), and

4. The loss of value due to sustained low retention in a given YOS group depresses the value of the entire force structure (Figure 12).

Utilizing the human capital market value models developed in this paper, it was possible to quantify the impact of retention on force structure value. The use of market value as a current value metric has the advantages of providing a straightforward way to apply human capital theory. The

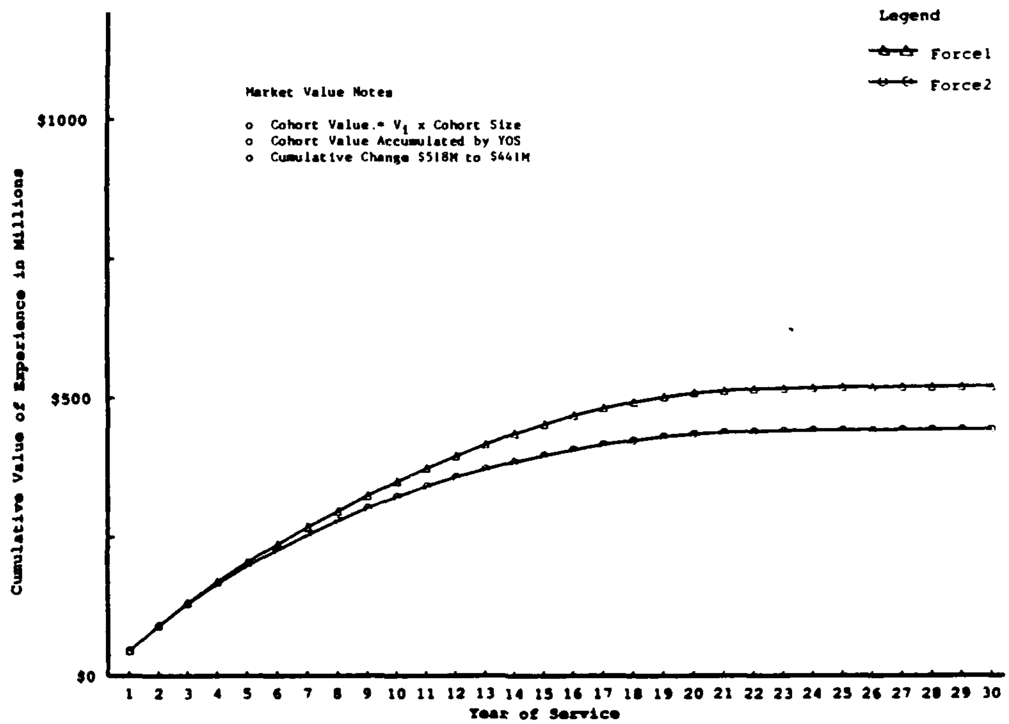


Figure 12. Force Structure Value

market value concept, however, provides only an aggregate metric more applicable to civilian than military occupations. Since the occupational matches are in broad groups and the Air Force does not generally bring in skilled individuals from the outside, the market approach, although of interest, fails to meet all the current value metric criteria established earlier. Application of a productive value concept which utilizes a metric more aligned to Air Force needs is presented in the next section.

APPLICATION OF PRODUCTIVE VALUE

To apply the productive value approach, equation (18) was used to develop a current value estimate with PTS and ATDPUTS values obtained from the ORDB. This productive value model incorporates all the features that an internal measure of current value should possess. These features are:

1. An accounting for both technical and supervisory work performed by an occupation,

2. A clear picture of changes in the percent time spent (PTS) in technical and supervisory activity, and

3. Technical and supervisory weights that estimate the relative contribution of those activities to force output.

The QRMC was used to develop the technical and supervisory weights required in the productive value approach. Figure 13 is a plot of productive value as defined by Equation (18).

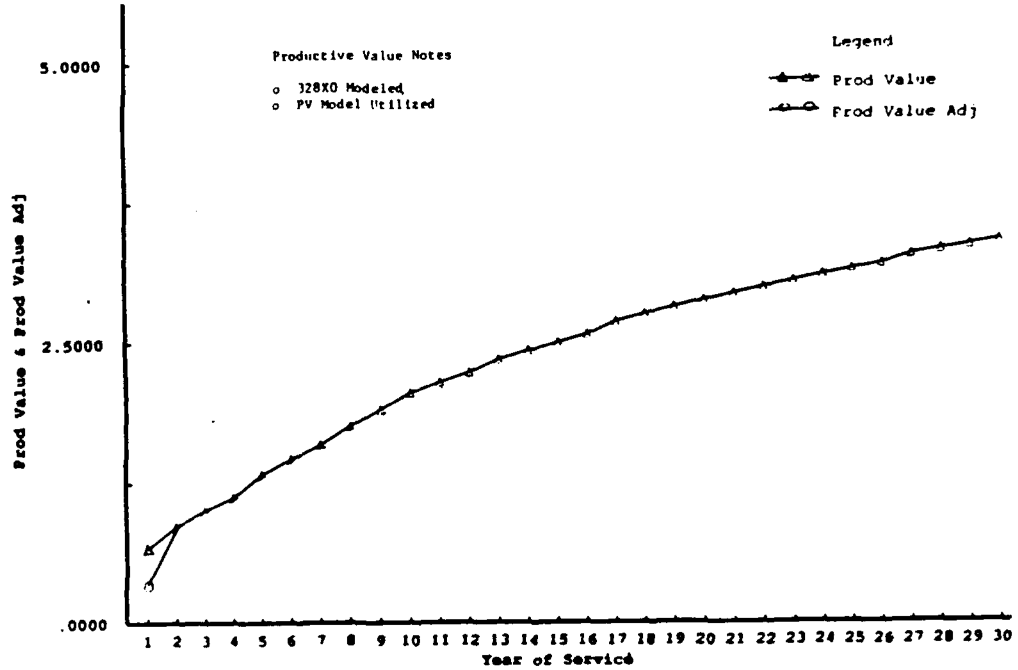


Figure 13. 328x0 Productive Value

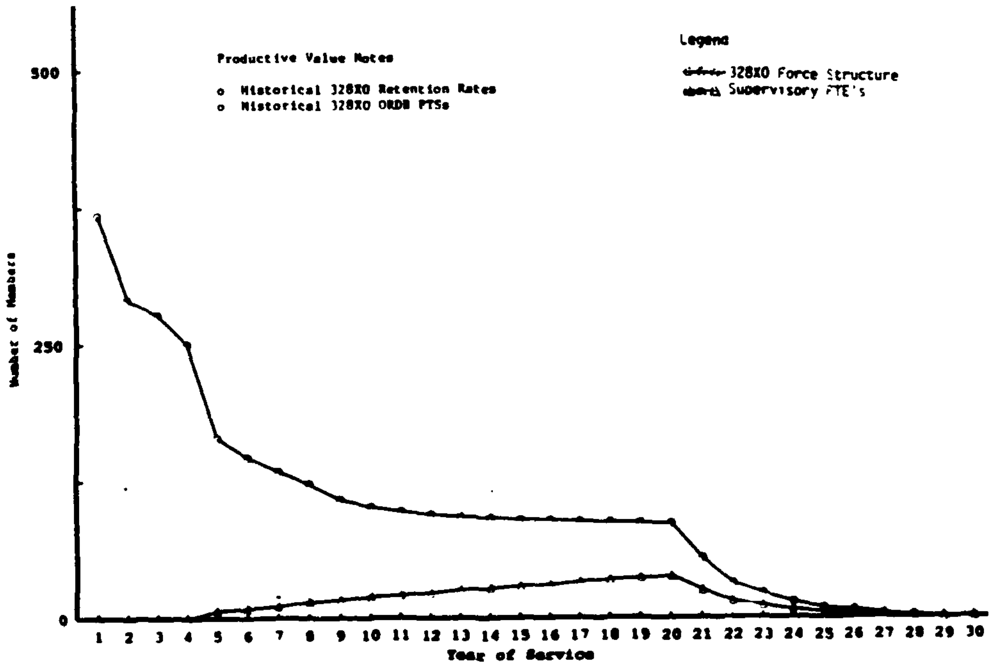
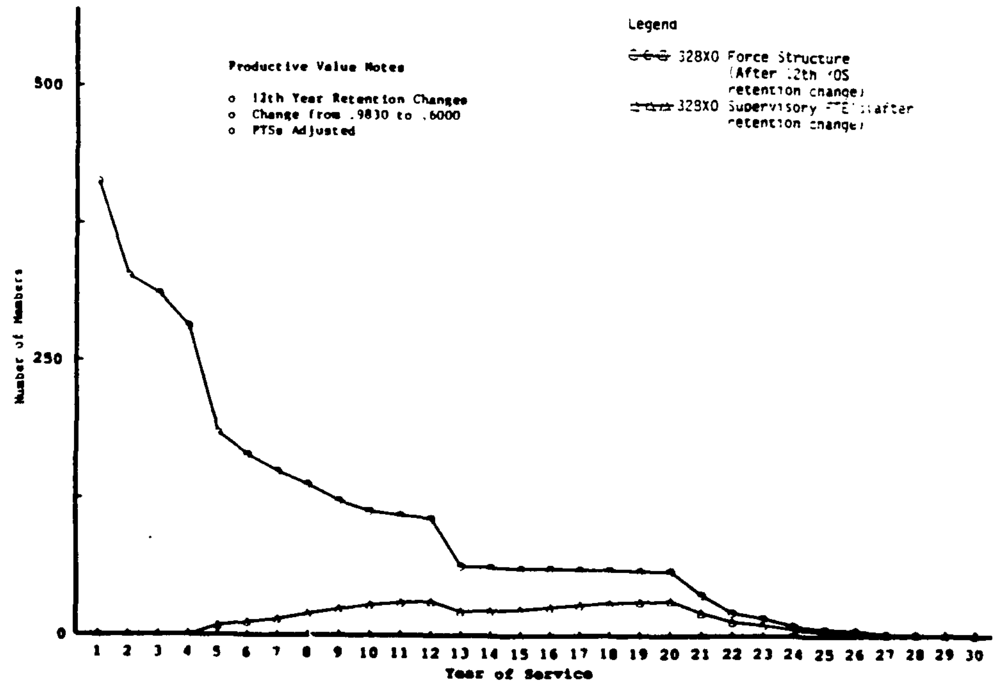


Figure 14. 328x0 Force Structure

The plot of the 328X0 force structure in Figure 14 is identical to Figure 8 in Section IV except for the inclusion of supervisory full-time equivalents (FTE) on the bottom of the plot. This line represents the PTS_s by YOS. In other words, the bottom plot shows that each YOS cohort spends an increasing number of FTE's until the 20 year point. Beyond that point, although the number of FTE's decreases (caused by smaller cohort size), the actual amount of supervisory time spent by these senior individuals increases. Figure 14 points out the need to keep an occupational perspective when developing a current value metric. Without an understanding of a force structure from an occupational perspective, the significant amount of supervisory work performed might have gone unidentified. Figure 14's picture of occupational activity shows how task inventories change and how various technical and supervisory weighting schemes impact the value of experience analysis.

Changing the retention rate of an AFS not only changes the force structure but changes the PTS_s by YOS. These changes are reflected in Figure 15 which shows an increased PTS_s to account for the smaller number of members in the latter year groups as a result of the 12th year retention change. There are fewer airmen in the older cohorts as retention decreases, but the total number of requirements stay fixed. Comparing Figures 14 and 15, the supervisory workload shift is evident. According to the ORDB reports, an insignificant amount of supervisory work was performed by first-term airmen in the 328X0 AFS. Therefore in Figure 15 it was assumed hat no supervisory duties were performed in the first term before or after retention changes were introduced. As retention decreases, however, the number of individuals capable of doing supervisory work decreases. A force structure with less retention will have fewer experienced members and will require at least as much, if not more, supervisory time resulting in increased PTS_s for the remaining experienced airmen.

In the productive value approach, the current value of a force structure changes when retention changes. This phenomena is illustrated in Figure 16 where the value of more experienced cohorts increases since less retention means more supervisory duties that increase PTS_s.



<u>Figure 15</u>. Force Structure Profile Change

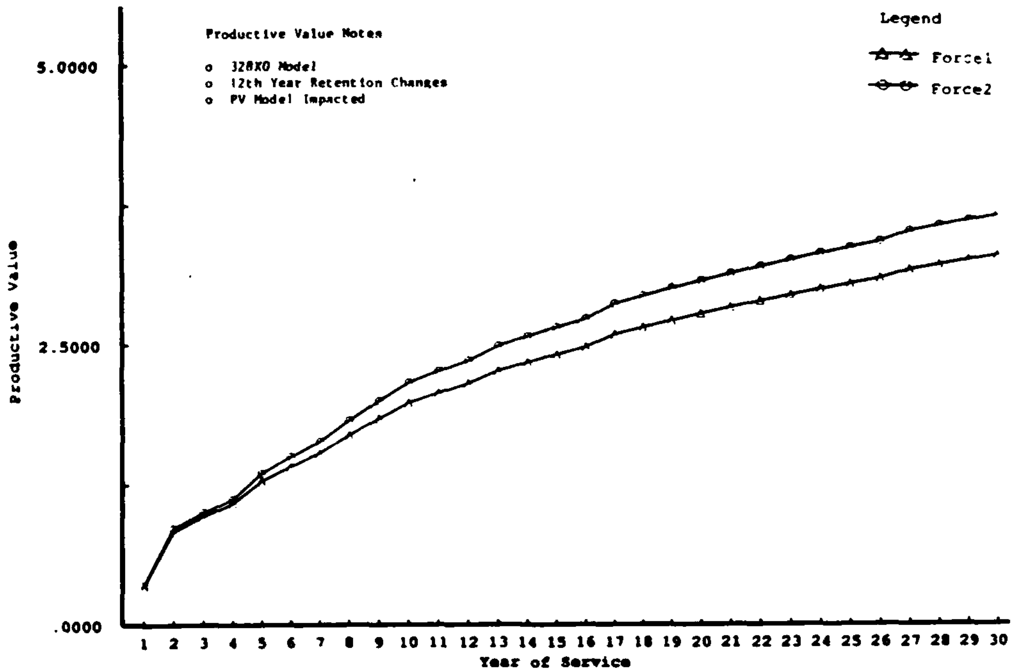


Figure 16. Productive Value Changes

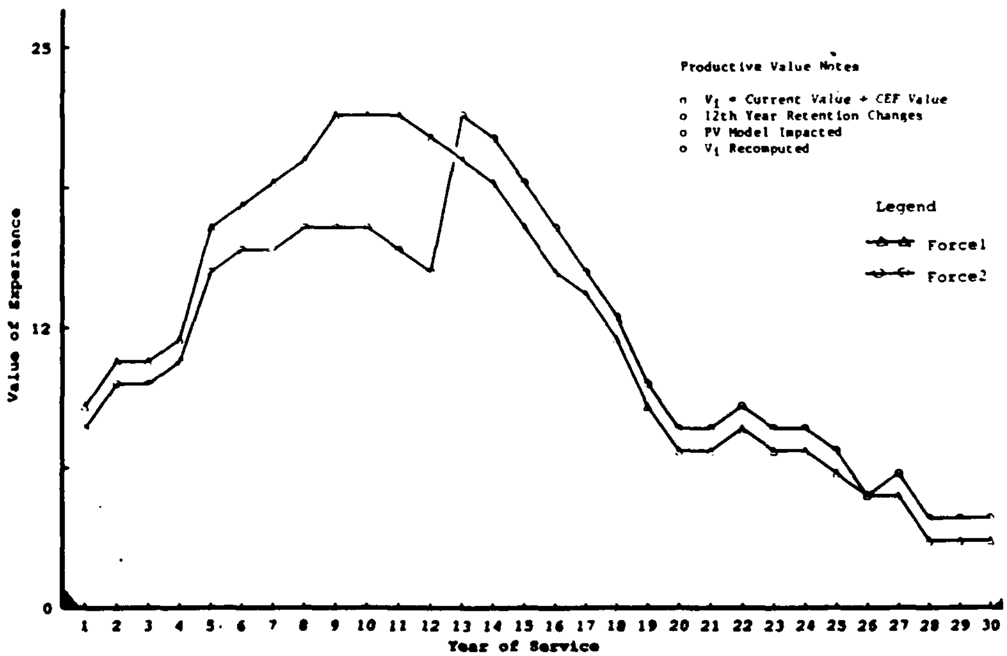


Figure 17. Value of Experience Changes

Since supervisory duties are weighted greater than technical duties, the current value of experienced technicians increases. Not only does retention impact the value of experience, but it also impacts the current value expression utilized to calculate V_i in equation (1). If a force structure possesses fewer experienced members, those members become more valuable since a greater percentage of their time must be devoted to supervisory as opposed to technical duties. Figure 17 shows that the value of experience by YOS dips in years preceding the retention decrease. This decrease is similar to the market value's Figure 13. But after the 12th YOS the value of experience of individual YOS groups increases due to the increase in PTS_s. The value of experience for YOS groups with more than 12 years of service is the major computational difference between the productive value and the market value approach. The productive value approach directly addresses an occupation's shifting task inventory and attributes higher value to resources that have now become more scarce through low retention patterns in previous years of the cohort's history.

The net result, in Figure 18, is a difference in cumulative force value between two alternative force structures similar to the market value difference observed in Figure 12. Changes in retention at any particular YOS point change the cumulative values of the overall force structure. With fixed force level requirements reduced retention results in a decrease in the average age of the force structure. Since the maximum value of experience occurs before the simulated reduced retention point in this example, the resulting younger average force decreases the overall cumulative value of the force structure.

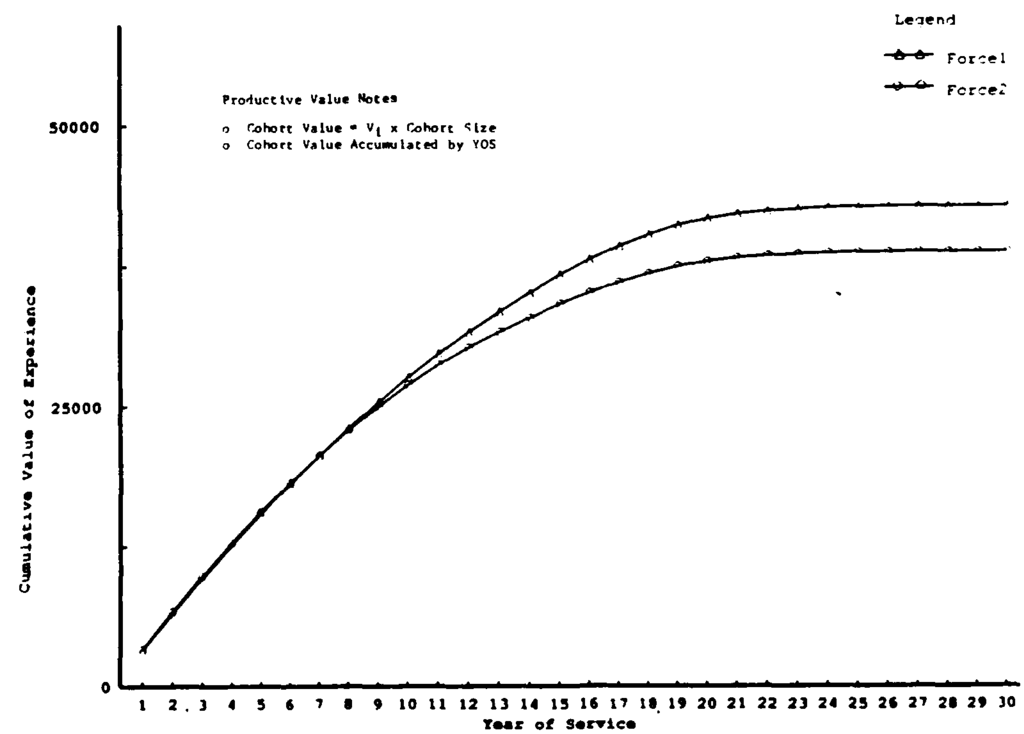


Figure 18. Force Structure Value

The productive value approach is more complex than the market value concept. In the market value approach, retention changed only the value of experience calculations. In the productive value approach, retention changed not only the value of experience (V_i) but also changed the current value

metric used to calculate V_i. Thus, the application in this section illustrates an improved process of determining the value of experience of an entire force structure. Some of the results observable from the application of the productive value approach are that:

1. All observations concerning the market value approach in Section IV are applicable to productive value,

2. The nature of changing task inventories must and can be accounted for using the productive value methodology, and

3. In the productive value approach, V_i is changed in years both before and after the year in which retention is changed.

The occupational emphasis used to develop the productive value approach has provided a systematic look at an occupation's activity. All work performed in an occupation is included since both technical and supervisory work effort is modeled. In addition, the relative contribution of these two kinds of work activities to force output is also addressed. This approach also requires that measures of technical performance, which are a function of experience, must be developed to adequately address the value of experience issue.

CONCLUSIONS

A method to assess the value of alternative force structures was developed utilizing human capital theory. The concept of a member's future contribution of services being of value to the Air Force today is the foundation of this approach. When appropriate retention rates and discounting factors were utilized, the concept allowed for the development of functional expressions that value an entire force structure or occupational specialty. This force structure metric can be used as a baseline to evaluate the changes in value caused by alternate retention patterns.

A market value approach to current value provided an aggregate metric applicable more to civilian than military jobs. The market value approach, however, did provide a simple model to illustrate value of experience calculations and provides insight into the difference between the value of technical and supervisory activity. Utilizing this metric, it was possible to examine the hypothetical impact of retention changes on force structure value. Sustained decreases in retention in any one year of service were observed to decrease the overall force structure value of an occupation.

To adequately address the value of experience concept, a current value estimate was constructed that accounted for the complexity of Air Force occupational activity. This complexity was captured in the productive value metric. This measure accounted for the change in an airman's productive capacity, percent time spent in technical duties, and the changing difficulty of those duties, as well as significant aspects of an airman's occupational activity.

The greatest lesson learned in this research effort is that a top down occupational view must be employed when developing an expression for current value. This view must include important aspects of work activity such as task inventory changes over a career. The productive value approach included the significant aspects of occupational activity. Significant supervisory activity must be accounted for in addition to the technical activity derived from TTP-like research.

It is strongly recommended that any future TTP work seek to establish an occupational taxonomy of duties as part of the measurement design study. This pre-measurement effort would classify all tasks into duties similar to present ORDB duty categories. These duty categories must be more than arbitrary clusters of tasks. To support value of experience and TTP needs, each duty (task cluster) must contain tasks with homogeneous levels of importance or value to the occupational groupings. This will provide a framework to rank order the duties among themselves.

Although the expression for productive value, equation (18), may appear at first sight complex, its complexity merely reflects the occupational phenomena it is intended to measure. There are ways of simplifying the expression for productive value (PV). In equation (18) PV is expressed as a function of ATDPUTS. $ATDPUTS_t$ across years of service is relatively flat. From a practical consideration, it was concluded that the $ATDPUTS_t$ term could be dropped since it added little additional information to the model of productive value. However, W_t and PTS_t must be included in the PV model and any other productive value model. The variance of $ATDPUTS_t$ was also narrow (-0.1184) and failed to distinguish the relative merit between tasks although its inclusion did improve the statistical correlation of the PV_t model.

Whether ATDPUTS is included or not, the basic form of Equation (18) is required as an internal measure of force output. Productive value accounts for the quantity and difficulty of work produced, the requirement for supervisory activity, and the relative contribution of differing activity to force output, each necessary for an adequate measure of productive value. This measure and the method developed in Section IV & V allow MPT resource managers to address a number of issues. Determining the impact of policies that would alter a given force structure's distribution could be addressed using the value of experience methodology. The value concept could also aid in defense against arbitrary reductions in military grade, skill level, or experience. It would also aid in placing a value on retention and recruiting initiatives required to modify existing occupational force structures. In this context, the concept of force structure value becomes a common denominator in which to examine a variety of issues.

Additional research is needed to refine the technical and supervisory weighting schemes. QRMC data were used for weighting development, but techniques such as "ratio scaling" (Williams & Crawford, 1980) may have application here. A solid measure of technical productive value, as defined in Equation (11), is necessary. This effort's productive value was developed using time-to-proficiency research. Exploring the link between TTP and the value of experience must continue. This step would ensure that any TTP measurement design would be initiated with the top down occupational considerations associated with the value of experience issue.

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APPENDIX A: 328XO DUTY CATEGORIES

DUTY	DESCRIPTION
A*	Organizing and planning
B*	Directing and implementing
C*	Evaluating and inspecting
D*	Training
E	Performing maintenance administration functions
F	Performing assist task qualification training (atqt) duties
G	Performing general aircraft avionic systems maintenance
H	Maintaining ultra high frequency (uhf) radio systems
I	Maintaining visual omni range/instrument landing (vor/ils) systems
J	Maintaining very high frequency (vhf) radio amplitude modulated (am) systems
K	Maintaining rendezvous radar beacon (rrb) systems
L	Maintaining very high frequency (vhf) radio frequency modulated (fm) systems
M	Maintaining radio/radar altimeters (rra)
N	Maintaining high frequency (hf) radio systems
O	Maintaining airborne identification systems
P	Maintaining interphone systems
Q	Maintaining tactical air navigation (tacan) systems and associated instrumentation equipment
R	Maintaining public address (pa) systems
S	Maintaining long range navigation (loran) and omega systems
T	Maintaining ultra high frequency (uhf) direction finder (df) systems
U	Maintaining automatic direction finder (adf) systems
V	Maintaining emergency radio (er) systems
W	Maintaining search and weather radar (sw) systems
X	Maintaining crash position indicating/crash data position indicating and recording (cpi/cdpir) systems
Z	Maintaining reconnaissance radar systems

*Classified as supervisory activity in this research

APPENDIX B: ATDPUTS DEFINITION

Average Task Difficulty Per Unit Time Spent (ATDPUTS) is an occupational measure of job inventory difficulty derived from structured field survey instruments. The percent time spent (PTS) on each task in a member's inventory is determined by administering a job inventory survey. The survey instrument contains all tasks in an AFS and asks the respondent to rank order on a scale of one to nine the relative time spent on each task.

Task difficulty is determined by senior members of a career field. These members are asked to rate the relative learning difficulty of all tasks in the job inventory on a nine point scale from extremely low to extremely high difficulty. Difficulty is defined in terms of the length of time required for an average member to learn to do a given task.

ATDPUTS is the computational result of percent time spent and task difficulty measurement. ATDPUTS for an individual member would be computed as follows:

TASK	PTS	DIFFICULTY	PTS x DIFF
A001	.02	9	.18
C078	.10	5	.50
E234	.23	4	.92
E239	.17	9	1.53
F172	.37	7	2.59
G009	.11	5	.55
	1.00		6.27

The ATDPUTS for this hypothetical airman was 6.27 which could be compared against other specialists performing in the AFS. The ATDPUTS measure does not show how much work is accomplished by a member, but provides the relative learning difficulty of a given inventory of tasks.

APPENDIX C: GLOBAL TECHNICAL PROFICIENCY

Global technical proficiency (GTP) is a metric that combines self, peer, and supervisor ratings. The rating scale consists of five levels which indicate the perceived frequency with which an individual meets the acceptable level of technical proficiency. The global rating provides a general overview of job performance, but may overlook performance on certain critical tasks. Global technical proficiency data were available for samples of first-term airmen from four AFSs. Global technical proficiency ratings were found to be significantly correlated with both performance and supervision time collected from the Time to Proficiency Questionnaire for the AFS 328X0. This suggested that global technical proficiency ratings possibly were reasonable surrogates for the production-oriented measure of merit derived from TTP.

For each airman, ratings of global technical proficiency obtained from the individual: self, a peer, and his/her supervisor, were averaged. This resulted in a more continuous measure, but was still confined to the interval [1, 5]. Beyond the first term, the modeled functional relationship between experience and GTP was restricted to the same closed interval. This was achieved using a logistic transformation of the averaged rating.

$$g(GTP) = \ln \left[\frac{GTP-1}{5-GTP} \right] \tag{C-1}$$

The following model was then estimated using weighted least squares

$$g(GTP) = b_0 + b_1 x\ Y \tag{C-2}$$

where: Y = experience expressed in YOS
b_0, b_1 = estimated parameters

The following transformation was made and extrapolated beyond the first term:

$$GTP = 1 + (4/(1 + e^{-b -bY})) \tag{C-3}$$

The slope of the extrapolated curve may be artificially small in later years because of the scale restriction, i.e. the predicted GTP cannot exceed 5, but may be close to 5 well before the thirtieth year. For AFS 328X0, the parameters were estimated to be 0.2112 and 0.4629 for b_0 and b_1 respectively.

Figure C-1 graphs the estimated and extrapolated relationship between GTP and experience for AFS 328X0. This relationship yields a candidate measure of productive value.

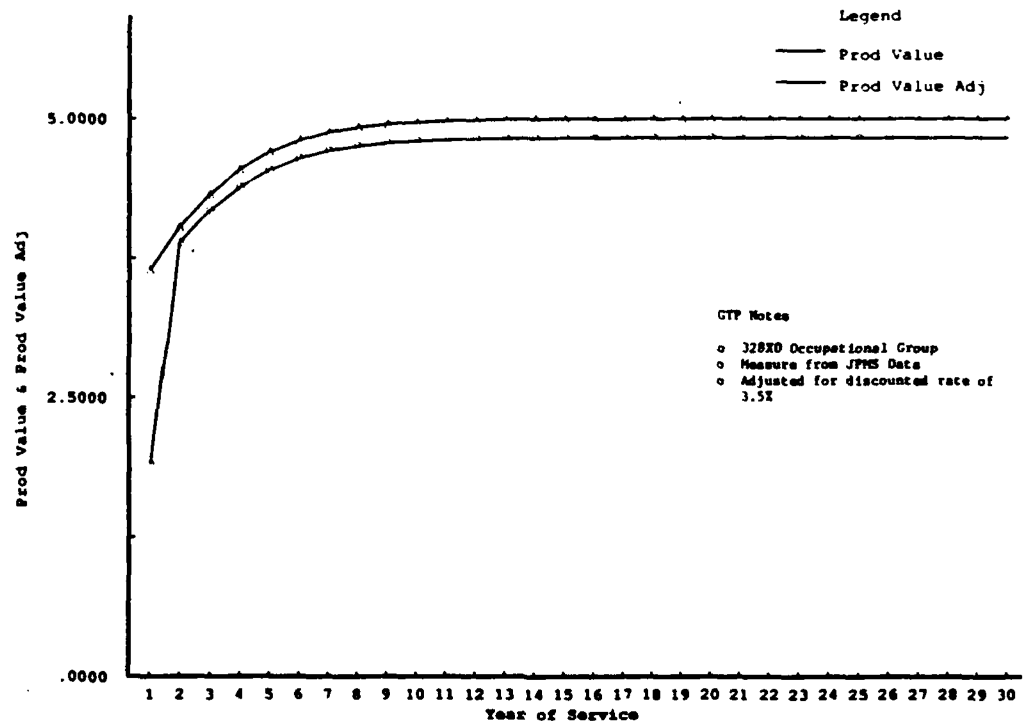

Figure C-1. Global Technical Proficiency

From Figure C-1, it is evident that the utility of the measure is limited. Its rapid increase to near maximum performance early in a career and then a leveling off during the later years does not make it intuitively appealing. This condition arises from the measure being confined to the interval [1,5] and the original data developed for use in describing first-term performance.

APPENDIX D: DISCOUNTING IMPACT

To look at the impact of discounting plots of the value of experience keeping market value and retention the same but varying the discount rate are shown in Figure D-1. Although the discount rate does change the value of experience plot it does not change the basic shape. Alternative force structures are not particularly sensitive to the level of discounting.

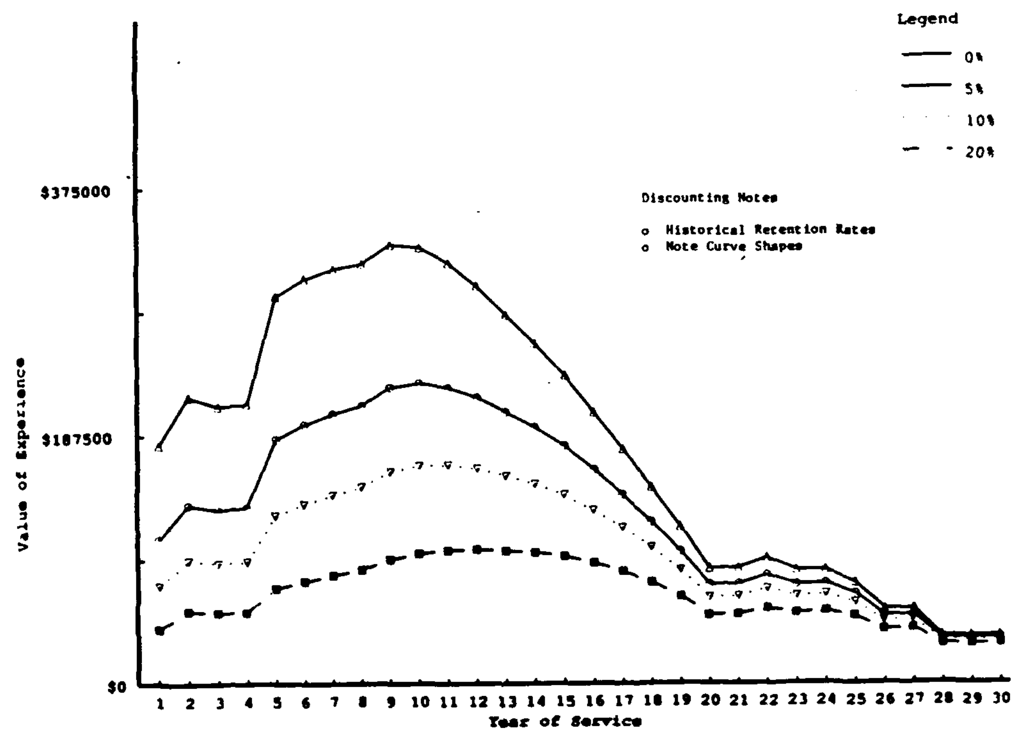

Figure D-1. Various Discount Rates